EXHIBIT D

PATENT
T3653-9295PV01

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NEW PROVISIONAL APPLICATION TRANSMITTAL LETTER

Sir:

Transmitted herewith for filing is the Provisional Patent Application of Inventor(s):

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PATENTS
T3653-9295PV01

For: xDSL Initialization In The Presence Of Impulse Noise

Enclosed are the following papers required to obtain a filing date under 37 C.F.R. §1.53(c):

__ Sheets of Informal Drawings
6 Pages of Specification, Drawings & Tables
__ Claims
__ Appendices
__ Standards

The following papers, if indicated by an ☒, are also enclosed:

☐ A Declaration and Power of Attorney
☐ An Assignment of the invention
☐ An Information-Disclosure Statement, Form PTO-1449 and a copy of each cited reference
☐ A Small-Entity Declaration
☒ A Certificate of Express Mailing, Express Mail Label No. ET 128795737 US

Basic Fee: $160

☒ A check in the amount of $160 is enclosed to cover the Filing Fee.

Please address all communications and telephone calls to the undersigned.

Respectfully submitted,

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PATENT
T3653-9295V01

UNITED STATES PROVISIONAL PATENT APPLICATION

of

Marcos C. Tzannes

for a

xDSL Initialization In The Presence Of Impulse Noise

XDSL Training in the Presence of Impulse Noise
By Marcos Tzannes

Background

Communication systems often operate in environments with Impulse Noise. Impulse Noise is a short-term burst of noise that is higher than the normal noise that typically exists in the communication channel. For example DSL systems operate on telephone lines and experience Impulse Noise from many external sources including telephones, AM radio, HAM radio, other DSL services on the same line or in the same bundle, other equipment in the home, etc. It is standard practice for communications systems to use Interleaving in combination with Forward Error Correction (FEC) to correct the errors caused by the Impulse Noise.

Standard initialization procedures in xDSL systems (such as those specified in ADSL ITU G.992 standards and VDSL ITU G.993 standards) are designed to optimize performance (data rate/reach) in the presence of "stationary" crosstalk or noise. Impulse noise protection is handled with Interleaving/FEC during data transmission mode (known as "Showtime" in ADSL systems), but the current xDSL initialization procedures (also known as "training procedures") are not designed to operate in an environment with high levels of Impulse Noise. As an example, there are several messages exchanged during initialization in ADSL and VDSL ITU standards that are not designed to work well in an environment with high levels of Impulse Noise. For example in ADSL2 G.992.3 standards there are initialization messages such as R-MSG-FMT, C-MSG-FMT, R-MSG-PCB, C-MSG-PCB, R-MSG1, C-MSG1, R-MSG2, C-MSG2, R-PARAMS, C-PARAMS, etc, which use modulation techniques that do not provide high levels of immunity to impulse noise. Likewise, for example, in VDSL1 G.993.1 standards there are initialization messages such as O-SIGNATURE, O-UODATE, O-MSG1, O-MSG2, O-CONTRACT, O-B&G, R-B&G, R-MSG1, R-MSG2, etc which use modulation techniques that do not provide high levels of immunity to impulse noise. Additionally, G.994.1 (G.hs), which is used as part of the initialization procedure for most xDSL standards, uses modulation techniques that do not provide high levels of immunity to impulse noise. In particular, for most of these message, a receiver will not be able to correctly demodulate/decode the message information if only 1 DMT symbol is corrupted by impulse noise. This is especially problematic because xDSL systems are generally designed to be able to pass steady-state ("Showtime") data without errors even when there is impulse noise that corrupts 2 DMT symbols. This means that, even though the xDSL system could operate in Showtime in an impulse noise environment where 2 DMT symbols are being corrupted, the transceivers would not be able to reach Showtime because initialization would fail due to initialization message failure.

Therefore there is a need for an improved initialization procedure for xDSL systems that operate in an environment with high levels of impulse noise.

Summary of the Invention

According to the principles of this invention, xDSL initialization messages are specifically designed to operate in an environment with high levels of impulse noise.

Aspects of this invention relate to repeating the transmission of DMT symbols that are used to modulate initialization message information bits to correctly receive the messages in an environment with high levels of impulse noise.

Aspects of this invention relate to using Forward Error Correction to encode and decode initialization messages to correctly receive the messages in an environment with high levels of impulse noise.

Aspects of this invention relate to using Forward Error Correction and Interleaving to encode and decode initialization messages to correctly receive the messages in an environment with high levels of impulse noise.

Aspects of this invention relate to using Error Detection Techniques, such as CRC, on portions of an initialization message to correctly receive the messages in an environment with high levels of impulse noise.

Aspects of this invention relate to using Error Detection Techniques, such as a CRC, on portions of the bits in an initialization message to correctly determine which DMT symbols are corrupted by impulse noise.

Aspects of this invention relate to using Error Detection Techniques, such as CRC, on portions of the bits in an initialization message to determine which DMT symbols are corrupted by impulse noise.

Aspects of this invention relate to using Error Detection Techniques, such as CRC, on portions of the bits in an initialization message to determine which bits are in error in a long message.

Aspects of this invention relate to using Error Detection Techniques, such as CRC, on portions of the bits in an initialization message and message retransmission to correctly receive messages in an environment with high levels of impulse noise.

Aspects of this invention relate to using Error Detection Techniques, such as CRC, on portions of the bits in any message or signal to determine which DMT symbols are corrupted by impulse noise.

Detailed Description

According to the principles of this invention, xDSL initialization messages are specifically designed to operate in an environment with high levels of impulse noise. The following is a list of some of the methods that can be used to address this problem:

DMT Symbol Repetition

In this case the DMT symbols that are used to modulate initialization messages are sent a plurality of times. This way, if one or more of the DMT symbols is corrupted by impulse noise, the receiver can still recover the information. In the simplest embodiment, a DMT symbol is simply repeated without modification and the receiver can use a variety of detection/demodulation schemes to recover the message information bits. For example, the receive could use "majority voting" where each DMT symbol is demodulated independently and then the message information bits are recovered by examining how many DMT symbols carry the same bit pattern. Alternatively, for example, the DMT symbols could examined by the receiver prior to demodulation in the frequency or time domain and based on these signals the receiver selects the most likely DMT symbol. In this case, for example, if a DMT symbol was repeated 4 times and 1 DMT symbol was corrupted by impulse noise then the receiver could examine the 4 DMT symbols in the frequency domain and clearly detect that 1 of the 4 symbols has a very different phase/amplitude characteristics than the other 3. Based on this, the receiver would discard the 1 DMT symbol that is corrupted by impulse noise and use the remaining 3 to demodulate and recover the information. In order to randomize the transmitted signal, the repeated DMT symbols can use phase or bit scrambling. In phase scrambling, the repeated DMT symbols can use different phase shifts on the subcarriers in order to randomize the signal. In bit scrambling, the information bits are scrambled prior to modulating them on the repeated DMT symbols.

FEC/Interleaving

xDSL systems often use FEC and Interleaving during Showtime to correct errors from impulse noise. But conventional xDSL transceivers do not use these techniques in initialization. In this invention, FEC with or without Interleaving can be used to correct impulse noise that corrupts messages during initialization. For example, prior to modulating the information bits of an initialization message, the message information bits could encoded using any well known FEC technique, such as Reed Solomon Codes, Hamming Codes, Convolutional Codes, Trellis codes, Turbo codes, LDPC codes etc. At the receiver, the FEC coding would be used to correct errors from impulse noise. For example, initialization messages could be encoded with a Reed Solomon (R-S) code using a codeword size N=K+R bytes, containing K message information bytes and R FEC checkbytes. This code can correct R/2 bytes. For example, if each DMT symbol is used to modulate 1 byte, and a R-S code with N=6 and R=4 was used, then the decoder would be able to correct R/2=2 bytes in each codeword. This corresponds to correcting 2 DMT symbols (assuming each DMT symbol carries 1 byte), which means that the receiver would be able to correctly recover the message information bits even if impulse noise corrupted 2 DMT symbols. Additionally, interleaving could be used to provide better immunity to impulse noise. For example, interleaving of multiple codewords could

be used to spread the errors from impulse over multiple codewords thereby enabling the receiver to correct impulse noise events that corrupt even more DMT symbols. As a simple example, 2 DMT symbols with N=6 and R=4 could be interleaved by simply transmitting 1 byte from the first codeword and then transmitting one byte from the second codeword and continuing to alternate transmission in this manner. In this case, assuming each DMT symbol carries 1 byte, an impulse noise that corrupted 4 consecutive DMT symbols would be correctable by the receiver because 4 consecutive DMT symbols would always be divided between 2 codewords with each codeword having the ability to correct 2 bytes (or 2 DMT symbols).

Adding Error detection capability in long messages

Long initialization messages (such as C/R-PARAMS in ADSL, C/R-B&G in VDSL and G.994.1 message) are particularly problematic when transmitted in then presence of impulse noise. This is because when a message is long it is very likely that some portion of the message will be corrupted by impulse noise and not be correctly recovered by the receiver. Although conventional xDSL systems use standard error detection methods (such as a Cyclic Redundancy Checksum (CRC)) this CRC covers the entire message and does not provide any information on which bits (or DMT symbols) were actually corrupted by the Impulse Noise. Therefore when a CRC error is detected in a message in conventional xDSL systems, the whole message is simply resent by the transmitter. But in an environment with high impulse noise, the retransmitted message is received in error as well and the retransmission process is simply repeated without success. In this invention, additional error detection capability is added to the messages to enable the location of bit errors in a long message. For example, a 1 byte CRC could be computed for each byte of the message. The CRC byte and the information could be modulated and transmitted on 1 DMT symbol (in this example 1 DMT symbol is carrying 2 bytes). At the receiver, the 2 bytes are demodulated and the CRC byte is used to detect if there was impulse noise corrupting this DMT symbol. If there the CRC shows no errors, then the receiver correctly receives this message byte. If there the CRC shows that there are errors, then the receiver needs to receive this DMT symbol again in order to correctly recover the information. In this example, 1 CRC byte is transmitted with 1 information bytes on each DMT symbol and the receiver can demodulate the entire message this way. If impulse noise has corrupted some of the DMT symbols in the long message, the message is retransmitted and the receiver performs a CRC check on those previously corrupted DMT symbols to determine if they are now received without errors. Since impulse noise is typically uncorrelated with the transmitted message signal, it is highly likely that different DMT symbols will be corrupted when the signal is retransmitted, which means that the receiver will probably receive the previously corrupted DMT symbols without errors the second time that the message is transmitted. In the unlikely event that the same DMT symbols are still in error, the message can be retransmitted again and again until all DMT symbols are received without errors. Note that upon retransmission it is likely that the impulse noise will cause errors in different DMT symbols than before. Therefore, the receiver stores the correctly-recovered message bits for DMT symbols from the previously received message. In fact the receiver can store all the previously received message bits that were received without error and simply use the

retransmitted message to correctly determine the message bits in the DMT symbols that were in error previously.
In one embodiment of this invention, the receiver actually sends a message to the transmitter requesting the transmitter to retransmit only the portion of the message that was previously received in error.
Obviously, although the examples above describe computing a CRC and adding a CRC byte to each byte in the message, a plurality CRC bits could computed for any number of bits in the message and transmitted to the receiver. Additionally, although the examples above describe modulating 2 bytes in each DMT symbol, any number of bits can be modulated on each DMT symbol. Additionally, although the examples above describe transmitting 1 CRC byte in every DMT symbol, any number of CRC bits can be modulated on each DMT symbol including (but not limited to) CRC bits being carried on only a subset of the DMT symbols. In this case, some DMT symbols will not have any CRC bits. As an example, 1 CRC byte could be computed for each 4 message bytes and each DMT symbol could carry 1 byte. In this case the first 4 DMT symbols would be used to modulate the message bytes and the 5th DMT symbol would carry the CRC byte. At the receiver, the CRC would be used to detect if any of the 5 DMT symbols was corrupted by impulse noise. If the CRC showed an error occurred, that the retransmission techniques described above would be used.

The methods described above can be done independently or in any combination.

Although the methods and components above were described in relation to initialization messages, they can broadly be applied to any Initialization or Showtime signal or message that needs to provide robust operation in the presence of impulse noise. Furthermore, the methods and components that use Error detection, such as CRC, to determine the location of an impulse noise event, can be broadly used to determine the location and duration of impulse noise events in any Initialization or Showtime signal or message.

The above-described communication components and methods can be implemented on wired and/or wireless telecommunications devices, such a modem, a multicarrier modem, a DSL modem, an ADSL modem, an XDSL modem, a VDSL modem, a multicarrier transceiver, a wired and/or wireless wide/local area network system, satellite communication systems, or the like, or on a separate programmed general purpose computer having a communications device. Additionally, the systems, methods and protocols of this invention can be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, modem, transmitter/receiver, or the like. In general, any device capable of implementing a state machine that is in turn capable of implementing the methodology illustrated herein can be used to implement the various communication methods, protocols and techniques according to this invention.

Furthermore, the disclosed methods may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed system may be implemented partially or fully in hardware using standard logic circuits or VLSI design. Whether software or hardware is used to implement the systems in accordance with this invention is dependent on the speed and/or efficiency requirements of the system, the particular function, and the particular software or hardware systems or microprocessor or microcomputer systems being utilized. The communication systems, methods and protocols illustrated herein however can be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed methods may be readily implemented in software executed on programmed general purpose computer, a special purpose computer, a microprocessor, or the like. In these instances, the systems and methods of this invention can be implemented as program embedded on personal computer such as JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication system, or the like. The system can also be implemented by physically incorporating the system and/or method into a software and/or hardware system, such as the hardware and software systems of a communications transceiver.

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